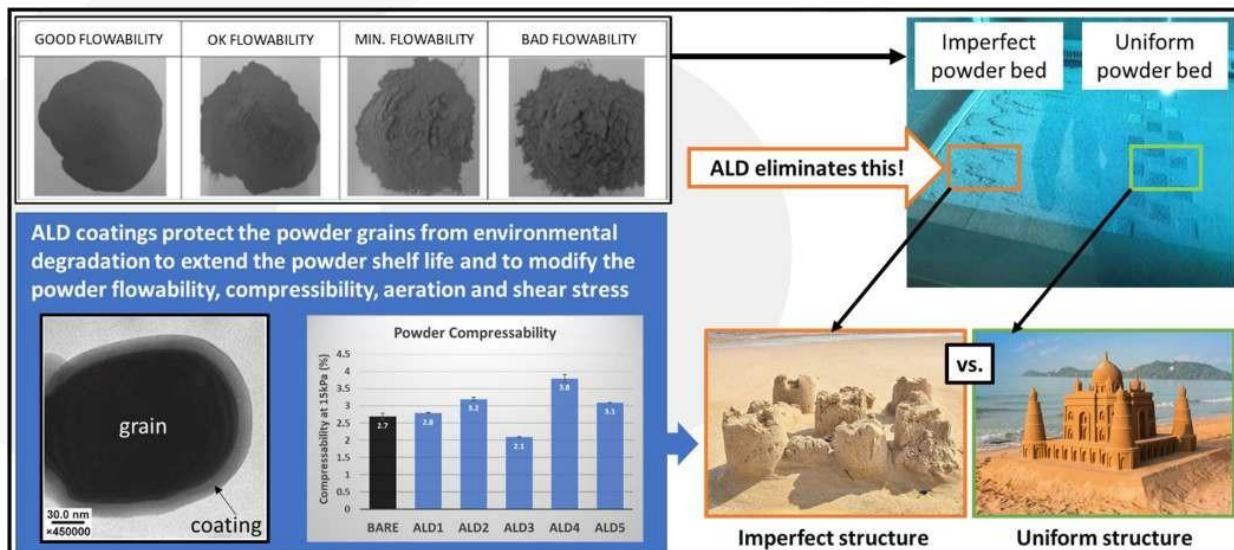


# Using Atomic Layer Deposition in Additive Manufacturing

While additive manufacturing has gained significant market traction in recent years with capabilities beyond traditional manufacturing, widespread adoption of 3D printing is hindered by limitations of the raw material. Limitations such as alloy type, flowability and oxidation resistance have been addressed with ALD and demonstrations have shown improved processing capabilities, stronger final parts and lower costs.

**Reduced Cost:** Employing ALD to improve powder properties can reduce costs by eliminating unnecessary processing steps. One example is the cost of Tungsten powder, which is typically in the range of \$30/kg, requires plasma spheroidization for successful flowability and printing which increases the cost by of the powder by 10x. By utilizing ALD to improve flowability instead of costly procedures such as plasma, the cost of Tungsten powder can remain low.

**Processing Improvements:** Forge Nano has demonstrated improvements to rheological properties of powders, such as flowability, bed density, oxidation protection, dispersion, crystallinity, corrosion resistance and shelf life, which enable improved homogeneity and reproducibility of parts, new alloy opportunities and use of nanomaterials.



**Parts Improvements:** ALD can improve mechanical properties such as strength, elongation and flexibility of printed parts through introduction of nucleants, or controlled nucleation sites, which alter the grain growth behavior during additive manufacturing printing, allowing for improved mechanical properties, electrical properties and more.



## About Forge Nano

Forge Nano is a leading materials science company harnessing the power of Atomic Armor, the company's proprietary ALD nanocoating technology, to accelerate manufacturing innovation, transform product performance and achieve a more sustainable future for a range of industries around the world. Atomic Armor produces superior coatings that can unlock a material's performance at the atomic level and deliver custom solutions from small-scale R&D and laboratory work to large-scale, high-volume production lines. A range of materials can be enhanced through Atomic Armor, including batteries, medical devices, catalysts, propellants and 3D additives. Forge Nano has received major support and signed meaningful partnerships with Volkswagen, LG Technology Ventures, Mitsui Kinzoku, Air Liquide and Sumitomo Corporation of Americas, largely as a result of the company's innovation in the Lithium-ion battery industry and successful track record of improving product performance and safety while reducing cost.

### Forge Nano's Capabilities

- **>20 in-house ALD systems for coating of wafers, powders and objects**
  - Including research, pilot and commercial scale systems capable of processing anywhere from 1.0 g to 30,000 kg powder or extrudates per day
  - Fast deposition times up to 30nm per minute for rapid Al<sub>2</sub>O<sub>3</sub> ALD coating solutions
- **The world's most knowledgeable and experienced team for ALD onto a range of materials**
  - PhD scientists, certified Professional Engineers, career scientists
  - 20+ years' experience designing and building powder ALD systems

### **Working with Forge Nano**

Forge Nano assists customers daily with both R&D and commercialization of ALD-enabled materials. For R&D, we offer research services for proofs of concept and also sell our R&D equipment globally. For commercialization, we offer joint development of products, production equipment and IP licensing.